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Review of the herpetofauna of Attica, mainland Greece

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Abstract

Although the insular distribution of the rich herpetofauna of Greece has been studied more extensively, the mainland one is still underexplored. The region of Attica in central Greece represents one of these "black spots" in the mainland. Thus, in 2019 we surveyed for the first time the herpetofauna of Attica in a systematic way. We collected 794 field records of 31 species (4 amphibians, 27 reptiles); *Testudo graeca* and *Trachemys elegans* were documented for the first time for Attica.

Key Words

amphibians, Greece, reptiles

Introduction

Greece hosts one of the richest (and locally well-studied) herpetofaunas in Europe, including 76 reptiles (12 endemic) and 25 amphibians (three endemic) (Valakos et al. 2008; Lymberakis et al. 2018). Starting with the French Morea Scientific Expedition (Expédition Scientifique de Morée 1828–1833), numerous naturalists were attracted by the herpetological wealth of Greece and realized extensive field work during the 19th century, describing several new species (Pafilis 2010). This trend has continued with an increasing number of herpetologists visiting Greece (Broggi 2019; Donihue et al. 2020). However, herpetologists, whether they were foreigners or (later) Greeks, had a clear preference to the "showcase" of the Greek herpetofauna – the islands (Christopoulos et al. 2019). As such, the mainland herpetofauna still remains understudied and broad areas have never been surveyed (Pafilis and Maragou 2013).

Attica, the historic region and geographic area where the cities of Athens and Piraeus are located, is no exception. Being a small peninsula at the southern-east part of central Greece (Fig. 1), for decades it served rather as a jetty to herpetologists who set off to visit the thousand Aegean islands that harbor some endemic taxa. As a result, although even some of the smallest islets have been surveyed (Pafilis et al. 2016, 2020), our knowledge about the herpetofauna of the mainland part of Attica is very poor. Even though the insular parts of Attica are well-studied (Clark 1967, 1970, 1989, 1997; Broggi 2016), the main body of the peninsula remains largely understudied, following the fate of mainland Greece herpetofauna contrary to the islands (Pafilis and Maragou 2013). The founding fathers of Greek herpetology made brief stops to Attica, reflected in rather laconic reports on the herpetofauna (Bedriaga 1883; Boettger 1888; Werner 1930, 1938; Cyrén 1941; Stepanek 1944). An important source comes from the botanist Theodor von Heldreich who wrote the first Fauna of Greece (1878). The chapters on reptiles and amphibians therein, present valuable information for Attica. The rest of our knowledge is based on checklists that typically reiterate previous findings (Ondrias 1968; Chondropoulos 1986, 1989; Valakos et al. 2008). According to this literature, Attica hosts 27 reptiles (10 lizards, 13 snakes and 4 turtles) and 4 amphibians. Here, we report the results of the first thorough and systematic herpetological survey of Attica aiming at identifying the current species composition and distribution.

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Methods

Study area

Hosting two of the main metropolitan centers of Greece (Athens and Piraeus), Attica is the most urbanized area in the country with close to 4 million inhabitants, representing over a third of the nation's population (ELSTAT 2011). Consequently, there are strong ecological pressures on the environment, the natural resources and wildlife, and many regions within Attica are of low environmental quality because of pollution, intense anthropogenic use and habitat fragmentation (Aperghis and Gaethlich 2006). However, Attica spans from 0 m a.s.l. to 1,413 m at Parnitha Mt. and still harbors impressive habitat diversity (Fig. 2), including wetlands, lowland croplands with olive groves and vineyards being the dominant type of cultivation for the past 5,000 years (Kouli 2012).

Land use in Attica comprises three major categories (Level 1; Corine Land Cover 2018). The terrestrial part of Attica covers 2,923.2 km^2. Artificial surfaces (ca. 26.0% of area) include the basic urban infrastructure, industrial, commercial and transport activities and is generally where most anthropogenic activities take place. Agricultural areas cover approximately 26.7%. Forested and semi-natural areas comprise 46.8%. This is a result of the numerous mountainous reliefs surrounding the major urban areas. Finally, a rather small percentage (0.8%) is covered by water, including inland and coastal wetlands, as well as other parts of the coast. Furthermore, the terrestrial part of Attica (2,923.2 km^2) comprises nine protected areas belonging to the Natura 2000 ecological network (446.96 km^2 or 15.3% of Attica) and one National Park (14.40 km^2 or 0.5%).

The climate is typically Mediterranean, with distinct, long and dry summers and short and wet winters. The highest temperature was recorded in July (46 °C) and the lowest in January (-8 °C), with an average annual temperature of 18.3 °C; rainfall is rather restricted (400–450 mm) (Gialamas 2013).

Data collection

Field work took place from mid-March to mid-August 2019, throughout the day (8–10+ hours of active field work, depending on the season) whenever weather conditions were seemingly optimal for surveying as many species as possible (clear sky, air temperature less than 37 °C, wind less than five on the Beaufort scale). Atti-

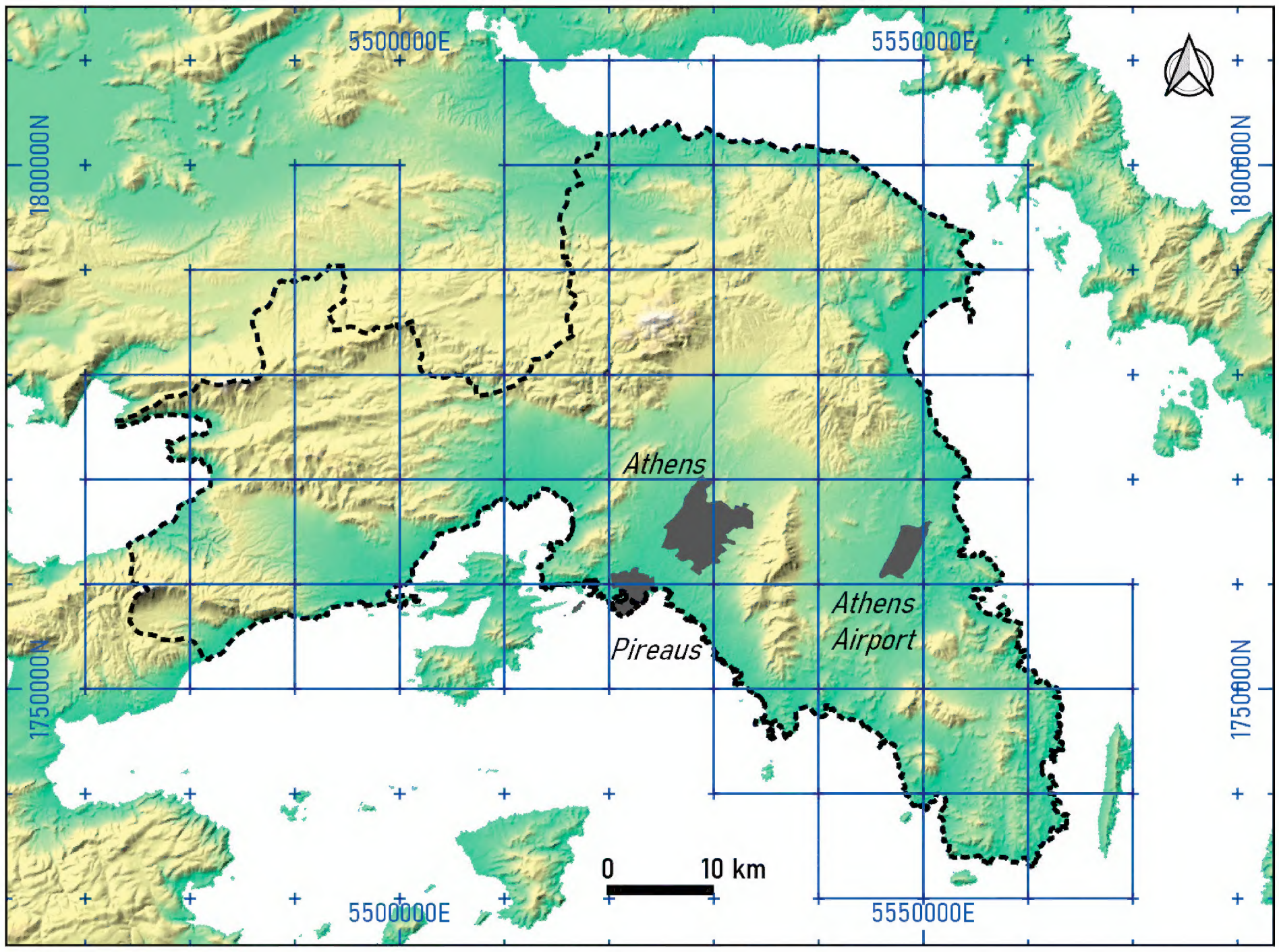

Figure 1. Map of the Attica peninsula at the east part of the central mainland Greece. The terrestrial part of Attica prefecture (dotted line, study site) was divided into a grid of 53 squared cells (10×10 km) according to the European Reference Grid.

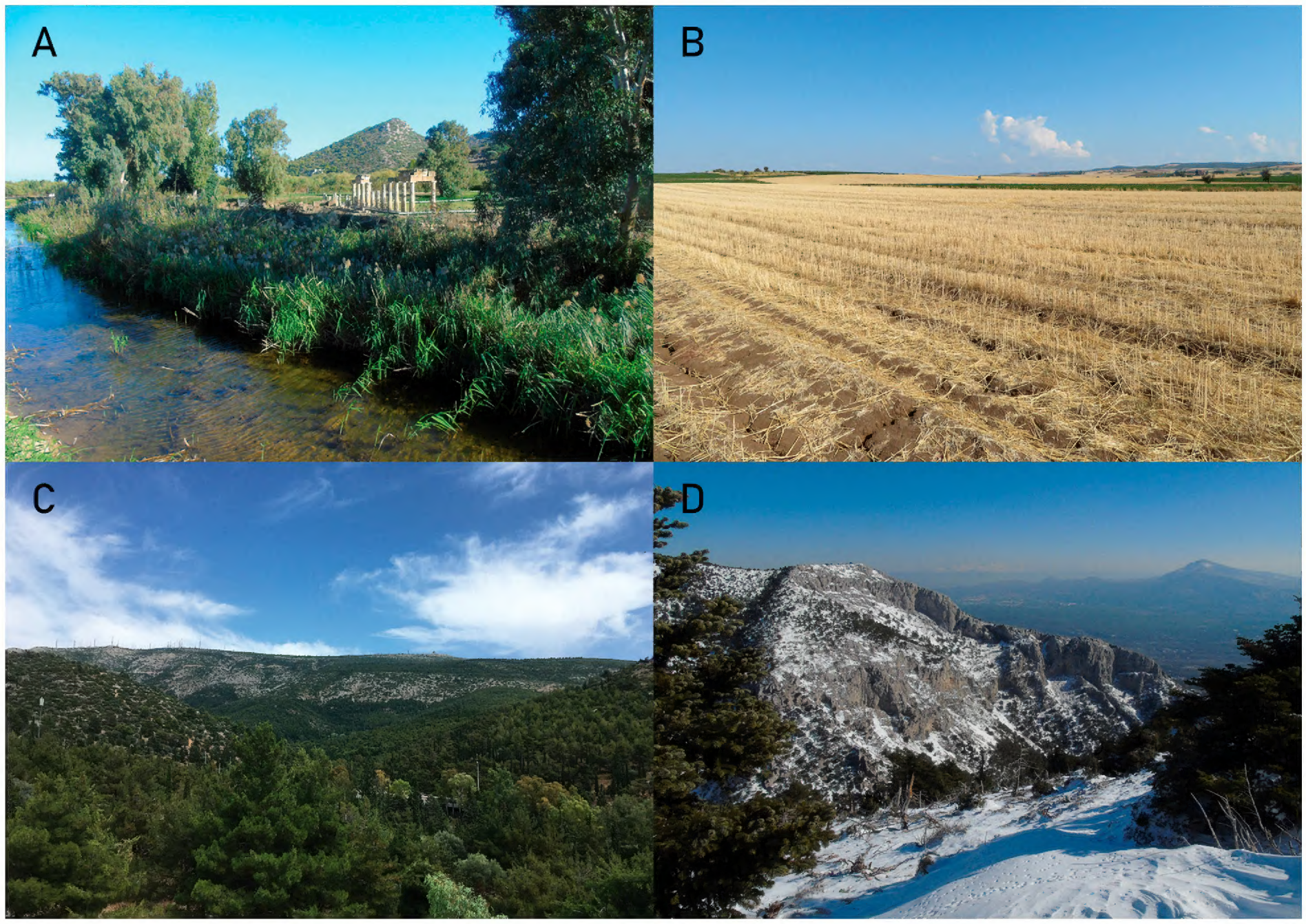

Figure 2. Different habitat types in Attica: **A.** The small river Erasinos by the ancient Artemis Temple at Vravrona (east Attica); **B.** Barley cultivations at Erythres plain (west Attica); **C.** Hymettus Mt. foothills, just next to Athens metropolitan area (central Attica); **D.** Winter landscape from Parnitha Mt. with Penteli Mt. in the far distance (north Attica).

ca falls into 53 (14 complete and 39 partial) squares of the 10×10 km European Reference Grid (Suppl. material 1: Fig. S1). Field work was arranged so as to have at least two sampling days in each sampling square, one during the spring and one in the summer. Six squares were excluded from sampling either because of previous wildfires or heavy urban development. In total, 158 sites were sampled (avg. 3 sites per square) within 92 days of field work.

At every site we (three people at least) visually surveyed for conspicuous species (e.g. lacertid lizards, turtles). We employed the line transect method and recorded and identified all reptiles and amphibians found on both sides (2 m) of the pathway (Lovich et al. 2012; McDiarmid et al. 2012). In each site we walked at least 6 tracks of 200 m (fixed distance measured with GPS). Furthermore, we devoted a considerable amount of time (1–2 hours, depending on the site characteristics) to overturn rocks, logs and debris and to search in vegetation for more cryptic species such as snakes, legless lizards and toads. Additionally, we visited most known sites that contained aquatic habitats (e.g. rivulets, ponds, lakes, marshes) and which are not that common in Attica. We visually surveyed the water surface and swept underwater with a dip net (net opening: 0.3 cm, pole length: 2.3 m) for 30 minutes (Heyer et al. 1994). Finally, we recorded all roadkill and shed snake skin encountered that we could identify to the species level. A hand-held GPS device was used to record the exact coordinates of each observation. Species taxonomy follows Uetz et al. (2020).

To assess the diversity of amphibians and reptiles in Attica, we calculated species richness, Shannon's diversity index (H') and Pielou's evenness index (J'). Species richness refers to the total number of species recorded per grid cell. Shannon diversity index (H') was calculated as:

$$H' = -\Sigma(p_i \cdot \ln(p_i)),$$

where p_i is defined as the proportion of the locations of species "*i*" to the total number of locations for all species. The evenness was represented by Pielou's evenness index:

$$J' = H' / H'_{max},$$

where H' is the number derived from the Shannon diversity index and H'_{max} is the maximum possible value of H' (if every species was equally likely).

Diversity indices were calculated in R 3.6.2 (R Core Team 2019) using the "vegan" package (Oksanen et al. 2019).

Results

We recorded 31 species based on 794 observations (Table 1). Amphibians were represented by 4 species that were concentrated mainly in the north (Fig. 3). We encountered 8 species of lizards, 13 snakes and 6 turtles (Fig. 3). However, only a handful of species were really

Table 1. Amphibians and reptiles in Attica, by family. The first citations from Attica, the number of records and the equivalent percentages. All species records for Attica were confirmed except for the European green lizard (*Lacerta viridis*) and the Greek snake skink (*Ophiomorus punctatissimus*).

Family/species	Cited in literature	Number of records	Percentage of records
Amphibia		189	**100%**
Bufonidae			
Bufo bufo	von Heldreich 1878	14	7.4%
Bufotes viridis	von Heldreich 1878	18	9.52%
Hylidae			
Hyla arborea	von Heldreich 1878	2	1.05%
Ranidae			
Pelophylax kurtmuelleri	von Heldreich 1878 (as *Rana esculenta*)	155	82.01%
Sauria		320	**100%**
Anguidae			
Pseudopus apodus	von Heldreich 1878	18	5.62%
Gekkonidae			
Hemidactylus turcicus	Expéd. Scient. de Morée 1833	8	2.5%
Mediodactilus kotschyi	Bedriaga 1883	10	3.12%
Lacertidae			
Lacerta trilineata	Cyrén 1941; Werner 1938	138	43.12%
Podarcis erhardii	Cyrén 1941; Werner 1938	8	2.5%
Podarcis muralis	Cyrén 1941; Werner 1938	8	2.5%
Scincidae			
Ablepharus kitaibelii	Werner 1938, Cyrén 1941	32	10%
Chalcides ocellatus	von Heldreich 1878; Werner 1938; Cyrén 1941	98	30.62%
Ophidia		121	**100%**
Colubridae			
Coronella austriaca	von Heldreich 1878	2	1.65%
Elaphe quatuorlineata	von Heldreich 1878; Bedriaga 1883; Boettger 1888	6	4.95%
Hierophis gemonensis	Boettger 1888	7	5.78%
Zamenis situla	von Heldreich 1878; Boettger 1888; Werner 1912	3	2.48%
Dolichophis caspius	Werner 1938	1	0.82%
Platyceps najadum	von Heldreich 1878; Werner 1912, 1930	8	6.61%
Telescopus fallax	Boettger 1888; Werner 1938	3	2.48%
Malpolon insignitus	Werner 1938; Stepanek 1944	32	26.44%
Erycidae			
Eryx jaculus	Boettger 1888; Cyrén 1941; Werner 1930	1	0.82%
Natricidae			
Natrix natrix	von Heldreich 1878; Boettger 1888; Werner 1912; Cyrén 1941	14	11.57%
Natrix tessellate	von Heldreich 1878; Boettger 1888; Werner 1938; Cyrén 1941	2	1.65%
Viperidae			
Vipera ammodytes	Boettger 1888; Werner 1912	26	21.48%
Typhlopidae			
Xerotyphlops vermicularis	Boettger 1888; Werner 1938; Stepanek 1944	16	13.22%
Turtles		164	**100%**
Emydidae			
Emys orbicularis	Expéd. Scient. de Morée 1833	1	0.06%
Trachemys scripta		2	1.83%
Geoemydidae			
Mauremys rivulata	Expéd. Scient. de Morée 1833	33	20.12%
Testudinidae			
Testudo graeca		3	1.83%
Testudo marginata	Werner 1930	118	71.95%
Testudo hermanni	Expéd. Scient. de Morée 1833	6	3.65%

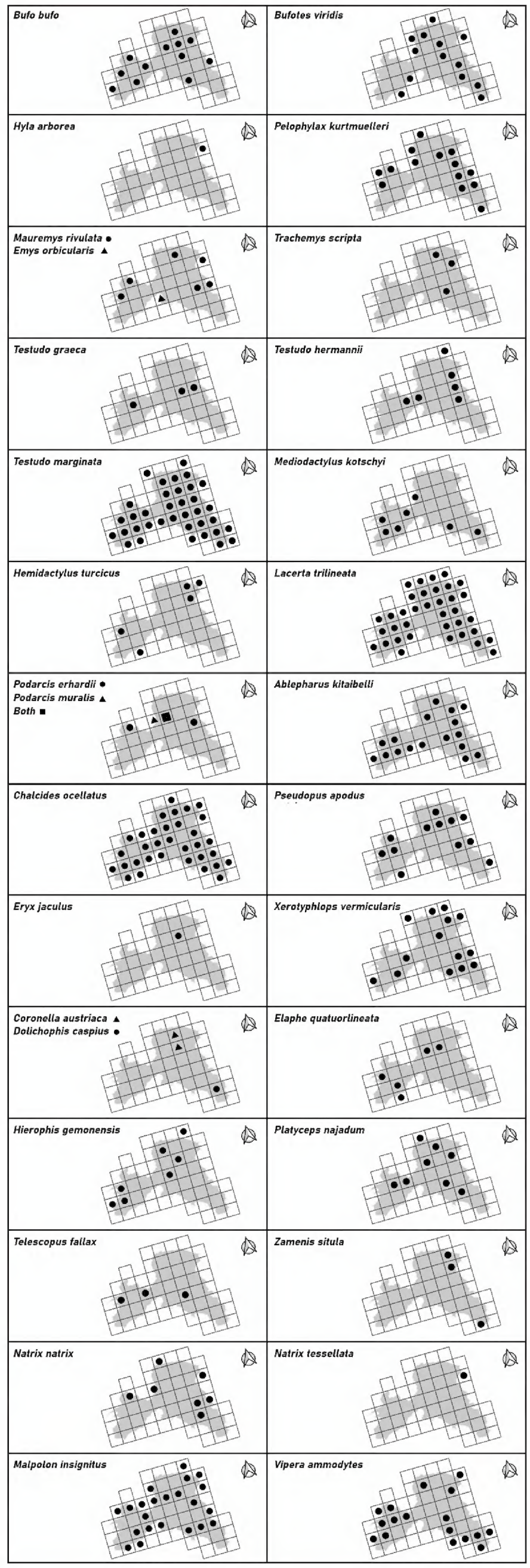

Figure 3. Amphibian and reptilian species distribution in Attica, mainland Greece, superimposed on the 10×10 km European Reference Grid. Circles, triangles and squares represent occurrence in a cell.

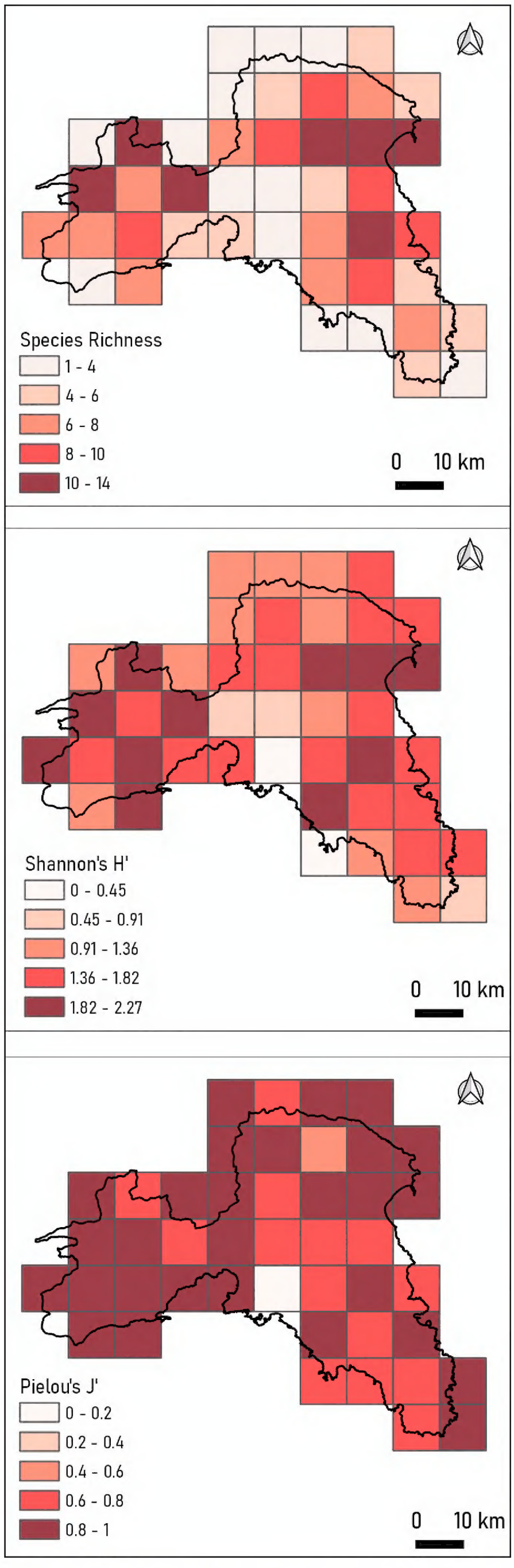

Figure 4. Amphibian and reptilian diversity in Attica: Species richness (top), Shannon's H (middle), Pielou's J' (bottom).

abundant (based on the number of observations). Among lizards, the most common species by far were the Balkan green lizard (*Lacerta trilineata*) and the ocellated skink (*Chalcides ocellatus*), comprising 73.7% of all records (Table 1). Among turtles, the marginated tortoise (*Testudo marginata*) represented 71.95% of the records of chelonians (Table 1). The more common snakes were the nose-horned viper (*Vipera ammodytes*) and the eastern Montpellier snake (*Malpolon insignitus*) (Table 1). Finally, the most frequently observed amphibian was the Balkan frog (*Pelophylax kurtmuelleri*) with 82.01% (Table 1).

We verified the presence of all species that have been reported in the literature, except for two: the European green lizard (*Lacerta viridis*) and the Greek snake skink (*Ophiomorus punctatissimus*) (Table 1). Also, the presence of the Erhard's wall lizard (*Podarcis erhardii*), considered almost extinct from Attica (Dimitropoulos and Gaetlich 1986), was recorded in three different sites. Two species that were not mentioned before, the Greek tortoise (*Testudo graeca*) and the invasive red-eared slider (*Trachemys scripta elegans*) were detected during fieldwork.

Species richness and Shannon's H' index show that herpetofauna diversity was higher in the less disturbed areas (Fig. 4). We found 22% of records in Natura sites, 23% in wetlands, 23% in mountain areas and 32% in cultivations. Pielou's evenness index J' on the other hand underlines a uniform pattern of occurrence (Fig. 4). Natura sites hosted the fewest individuals but most species (199 records, 24 species) compared to the rest types of biotopes, highlighting the importance of *ex situ* preservation.

Discussion

In this study we assessed for the first time the herpetofauna of Attica in a systematic way. Our findings corroborate the presence of almost all species reported in the past. Of the species we did not detect, *O. punctatissimus* was only reported by Bedriaga (1883) and further reports (Bischoff 1981, Chondropoulos 1986) refer to Bedriaga's finding. According to recent research on its systematics, *O. punctatissimus* is limited to the Peloponnese peninsula south of Attica, two islands, and one mainland site (Iraion, Prefecture of Corinth) (Kornilios et al. 2018). It is dubious whether this species ever occurred in Attica. The *L. viridis* reported from Attica (von Heldreich 1878) has been later identified to be in fact *L. trilineata*; currently, *L. viridis* occurs only in northern Greece and does not occur in Attica (Valakos et al. 2008).

Though the species is reported in old checklists from Attica (Ondrias 1968), its current presence was strongly disputed. Apart from a single verified report in Parnitha Mt (Pafilis and Simou 2006), there were only speculations on its presence. We were able to verify the presence of *P. erhardii* in Attica in three locations. In the past, the species used to be common in Attica and von Wettstein (1953) referred to individuals that were collected in the mountains Hymettus, Penteli and Tourkovounia during the early 20th century. However, Cyren (1935) and Werner

(1938) mentioned that the species was already rare by the time they visited Attica. Dimitropoulos and Gaetlich (1986) reported that many of the Attic populations have been extinct and "the species is likely to soon disappear from the whole of Attica". Thus, we were surprised to spot three *P. erhardii* populations besides that in Parnitha Mt., two at Penteli Mt. (15 km from each other) and one in the Erythres plain at the west of Attica (Fig. 4). It is hard to tell whether our findings reflect recently settled populations or old ones that were re-discovered thanks to systematic field work. The habitat types where the species was found (maquis and phrygana) are very common in Attica, and thus it is possible that new populations may be revealed in the future.

We also recorded for the first time in Attica three individuals of the Greek tortoise (*T. graeca*), at three places (Fig. 3). This species normally occurs in central and northern Greece and on islands of northeastern Aegean Sea. Nonetheless, we should highlight that this species is widely used as a pet and might have been anthropogenically transported to places outsides its natural range. Whether such, putatively, transferred animals may pave the way for new populations is something to survey in the future. Another chelonian species, the European pond turtle (*E. orbicularis*) was found in Attica in only one location (Fig. 3). Fresh water bodies, and especially unpolluted ones, are a rare commodity in the area, and thus this species cannot sustain viable populations. However, we cannot rule out the possibility of human transportation, a common practice for many chelonians. Indeed, that was the way the invasive *T. scripta elegans* was introduced in Attica. During our field work, we detected three populations (first record for Attica) in places receiving high human traffic for recreation activities. It is not known yet whether these populations are sustained by people releasing new animals or if the local *T. srcipta elegans* are able to reproduce as in other countries in south Europe.

Two invasive species that were recently recorded in the Athens metropolitan area, the Italian wall lizard (*Podarcis siculus*) (Adamopoulou 2015) and the Andalusian wall lizard (*Podarcis vaucheri*) (Spilani et al. 2018) have seemingly not dispersed much beyond the locations of the original sightings. The same goes for other native species with different origin that were found inside the Athenian urban districts like the common wall gecko (*Tarentola mauritanica*) (Strachinis and Pafilis 2018), the Peloponnese wall lizard (*Podarcis peloponnesiacus*) (Hedman et al. 2017) and the Greek Algyroides (*Algyroides moreoticus*) (Deimezis-Tsikoutas et al. 2020). Apparently, all these species arrived in Athens thanks to humans, but their dispersal so far seems to be limited to urban areas and did not affect the rest of Attica, at least so far.

As mentioned earlier, fresh waters are not common in Attica. This fact explains the limited number of amphibian observations (Fig. 3). In particular, species that need high air humidity and permanent water bodies, like the European tree frog (*Hyla arborea*), seem to be very rare in Attica. Snakes on the other hand were ubiquitous and with the highest diversity among all sampled groups (Fig. 3). Attica's environmental and ecological conditions support both high snake diversity and abundance and this is obvious by their large numbers. In addition, people living in Attica have more positive behaviors when encountering snakes compared to those inhabiting provincial Greece where killing snakes on sight is the rule.

According to our results, diversity was higher in areas that were seemingly less impacted by human activities (Fig. 4). The species richness and Shannon's H' index follow a similar pattern, with most species concentrated on or around the relatively undisturbed mountainous masses of Attica. Pielou's evenness index J' shows a rather uniform pattern with relatively high values. This may imply communities without strongly dominant species, where in both rich and poor communities, the abundances of individual species are not highly different.

More herpetological surveys on Attica will shed light on the occurrence of cryptic species, such as *O. punctatissimus*, the presence of which cannot be ruled out with certainty. Also, future surveys are urgently required to monitor potential further dispersal of the alien species that recently invaded Athens metropolitan area and may expand to the rest of Attica with important effects on the local herpetofauna.

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Supplementary material 1

Figure S1

Authors: Ioannis Annousis, Grigoris Kapsalas, Panayiotis Pafilis
Data type: png image
Explanation note: Grid cell codes following the EEA Grid nomenclature.
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Link: https://doi.org/10.3897/herpetozoa.34.e60668.suppl1

Supplementary material 2

Table S1

Authors: Ioannis Annousis, Grigoris Kapsalas, Panayiotis Pafilis
Data type: doc. table
Explanation note: The exact location for all records. The number of individuals found per locality. Other findings such as road kill (RK) and snake shirt (SS).
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Link: https://doi.org/10.3897/herpetozoa.34.e60668.suppl2